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Address to:
Box Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

Attorney's Docket No. COHD-3252

First Named Inventor Jörg Lawrenz-Stolz

UTILITY PATENT APPLICATION TRANSMITTAL
(under 37 CFR 1.53(b))

SIR:

Transmitted herewith for filing is the patent application by Jörg Lawrenz-Stolz, entitled:
AN ASSEMBLY FOR FOCUSING AND COUPLING THE RADIATION PRODUCED BY A SEMICONDUCTOR LASER INTO OPTICAL FIBERS

CERTIFICATION UNDER 37 CFR § 1.10

I hereby certify that this New Application and the documents referred to as enclosed herein are being deposited with the United States Postal Service on this date April 1, 1999, in an envelope bearing "Express Mail Post Office To Addressee" Mailing Label Number EL059098092US addressed to: Box Patent Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

Lana T. Brenner
(Name of person mailing paper)

(Signature)

Enclosed are:

1. X Transmittal Form (two copies required)

2. The papers required for filing date under CFR § 1.53(b):
   i. 26 Pages of specification (including claims and abstract);
   ii. 2 Sheets of drawings.
   __ formal X informal

3. Declaration or oath

   a. __ Newly executed (original or copy)

   b. X Copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Item 12 completed)

   X Incorporation By Reference (to be used if Item 3b is checked)

   The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Item 3b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

   i. __ DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b)

4. __ Microfiche Computer Program (Appendix, see 37 CFR 1.96)

5. __ Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
   i. __ Computer Readable Copy
   ii. __ Paper Copy (identical to computer copy)
   iii. __ Pursuant to 37 C.F.R. §1.821(g), the undersigned has reviewed the paper copy and the computer readable copy of the Sequence Listing and determined the information recorded in computer readable form is identical to the written Sequence Listing.

ACCOMPANYING APPLICATION PARTS

6. __ An assignment of the invention to ______________ is attached (including Form PTO-1595).

   X The prior application is assigned of record to COHERENT, INC.;
   Assignment recorded in PTO on March 30, 1998, Reel 9093, Frame(s) 152.

__ The prior application is assigned, and the assignment (copy attached) was submitted to PTO for recording on __________.

i. __ 37 CFR 3.73(b) Statement (when there is an assignee)

7. __ Power of Attorney

8. X An Information Disclosure Statement (IDS) is enclosed, including a modified PTO-1449.

9. X Preliminary Amendment.

10. X Return Receipt Postcard (MPEP 503 -- should be specifically itemized)

11. __ Other

12. If a CONTINUING APPLICATION, ***check appropriate box and supply the requisite information***

__ Continuation
X Divisional
__ Continuation-In-Part (CIP)

of immediately prior application No. **08/982,018,** filed **December 1, 1997, which is a continuation of prior application No. 08/047,421, filed April 14, 1997.**

i. RELATE BACK - 35 USC 120: If one of the above boxes are checked, please amend the specification by inserting before the first line the sentence: --This is a [ ] continuation [X] divisional of Application No. 08/982,018, filed December 1, 1997, which is a continuation of prior Application No. 08/047,421, filed April 14, 1997.--

ii. MAINTENANCE OF COPENDENCY OF PRIOR APPLICATION
(This item must be completed and the necessary papers filed in the prior application if the period set in the prior application has run).
[ ] A petition, fee and response has been filed to extend the term in the pending prior application until ______.
[ ] A copy of the petition for extension of time in the prior application is attached.

iii. CONDITIONAL PETITIONS FOR EXTENSION OF TIME IN PRIOR APPLICATION
(Complete this item and file conditional petition in prior application if previous item (ii) not applicable).
[ ] A conditional petition for extension of time is being filed in the pending prior application.
[ ] A copy of the conditional petition for extension of time in the prior application is attached.

13. FOREIGN PRIORITY
[ ] Priority of application no. _________ filed on ______ in ______ is claimed under 35 USC 119.

The certified copy of the priority application:
__ is filed herewith; or
__ has been filed in prior application no. _________ filed on ______, or
__ will be provided.

__ English Translation Document (if applicable)

14. **FEE CALCULATION**

a. X Amendment changing number of claims or deleting multiple dependencies is enclosed.

b. X Cancel in this application original Claims 1-9, 11 and 13 of the prior application before calculating the filing fee.

CLAIMS AS FILED

	Number Filed	Number Extra	Rate	Basic Fee ($760)
Total Claims	10 - 20	* 0	x $18.00	0
Independent Claims	3 - 3	* 0	x $78.00	0
__ Multiple dependent claim(s), if any			$260.00	0

*If less than zero, enter "0".

Filing Fee Calculation $760

50% Filing Fee Reduction (if applicable) $0

15. Small Entity Status
   a. __ A small entity statement is enclosed.
   b. __ A small entity statement was filed in the prior nonprovisional application and such status is still proper and desired.
   c. __ is no longer claimed.

16. Other Fees
   __ Recording Assignment [$40.00] $0
   __ Other fees
   Specify ____________________ $0

Total Fees Enclosed $760

17. Payment of Fees
   X Check(s) in the amount of $ 760.00 enclosed.
   __ Charge Account No. 12-1420 in the amount of $______.
   A duplicate of this transmittal is attached.

18. All correspondence regarding this application should be forwarded to the undersigned attorney:

Michael A. Stallman
Limbach & Limbach L.L.P.
2001 Ferry Building
San Francisco, CA 94111
Telephone: 415/433-4150
Facsimile: 415/433-8716

19. Authorization to Charge Additional Fees

X The Commissioner is hereby authorized to charge any additional fees (or credit any overpayment) associated with this communication and which may be required under 37 CFR § 1.16 or § 1.17 to Account No. 12-1420. **A duplicate of this transmittal is attached**.

LIMBACH & LIMBACH L.L.P.

April 1, 1999
(Date)

By: [signature]
Michael A. Stallman
Registration No. 29,444
Attorney(s) or Agent(s) of Record

Attorney Docket No. COHD-3252

Express Mail Label No.: EL059098092US

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	Group Art Unit:
Jörg Lawrenz-Stolz	Examiner:
Application No. NEW	PRELIMINARY AMENDMENT
Filed: HEREWITH	
For: AN ASSEMBLY FOR FOCUSING AND COUPLING THE RADIATION PRODUCED BY A SEMICONDUCTOR LASER INTO OPTICAL FIBERS	2001 Ferry Building San Francisco, CA 94111 (415) 433-4150

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Prior to examining the above-identified application, please amend the claims as follows:

IN THE CLAIMS

Cancel claims 1-9

10. (amended) In a laser diode module wherein laser radiation from a linear laser diode array is coupled into a plurality of optical fibers corresponding in number to the number of laser diodes in the laser diode array, each of the optical fibers having a light entrance side, the invention characterized in that:

[the light entrance sides of] the optical fibers are mounted on a holder and arranged [parallel to each other in] so that the light entrance sides thereof form a linear array;

a cylindrical lens having at least the length of the linear laser diode array, [is glued onto said linear array of] said

cylindrical lens being attached directly to the light entrance side[s] of each of the optical fibers using a bead of glue in a manner to self center and align the cylindrical lens with respect to the light entrance sides independent of the holder; and

said linear array of light entrance sides of the optical fibers and said cylindrical lens glued thereon is aligned with the linear array of laser diodes for receiving radiation emitted therefrom and focussing said received radiation into said plurality of optical fibers.

Cancel claim 11.

12. (amended) The laser diode module claim [11] 10, the invention further characterized in that said cylindrical lens is a length of optical fiber.

Cancel claim 13.

14. (amended) The laser diode module claim [13] 10, the invention further characterized in that[, in step (c) said gluing is by means of] said bead of glue is an epoxy adhesive.

15. (amended) In a laser diode module wherein laser radiation from a linear laser diode array is coupled into a plurality of first optical fibers corresponding in number to the number of laser diodes in the laser diode array, each of the first optical fibers having a core diameter and a light entrance side, the invention characterized in that:

[the light entrance sides of] the first optical fibers are mounted on a holder and arranged [parallel to each other] so that the light entrance sides thereof form a linear array;

a second optical fiber having at least the length of the linear laser diode array, [is glued onto said linear array of] said second optical fiber being attached directly to the entrance side[s] of each of the first optical fibers using a bead of glue and centered thereon independent of the holder; and

said linear array of light entrance sides of the first optical fibers and said second optical fiber glued and centered thereon is aligned with the linear array of laser diodes for receiving radiation emitted therefrom and focussing said received radiation into said plurality of first optical fibers.

Please add new claims 19-21 as follows:

19. A light source for optically pumping a gain medium comprising:

a semiconductor laser structure having an array of emitter regions;

a plurality of optical fibers for carrying light emitted from the laser structure to a gain medium with the light entrance ends of the fibers being mounted on a holder and configured in a linear array spaced from the array of emitter regions of the laser structure; and

a single cylindrical lens for coupling the light from the emitter regions into the light

entrance ends of the fiber, said lens having a length at least as long as the array of light entrance ends, said cylindrical lens being attached directly to each of the light entrance ends by a bead of glue in a manner to center the lens on the light entrance ends to facilitate alignment independent of the holder.

20. A light source as recited in claim 19 wherein said cylindrical lens is an optical fiber.

21. A light source as recited in claim 19 wherein said optical fibers are multimode fibers.

REMARKS

In the parent application, the method claims were allowed, but the apparatus claims were rejected. In particular, in an amendment after final, the Examiner indicated that the amended apparatus claims raised new issues. Applicant is, therefore, resubmitting the apparatus claims in the form set forth in the response to the final action. The following remarks are taken from that response in the parent case.

The subject invention relates to a diodes laser module. The diode laser module of both the invention and the principal reference relied on by the Examiner in the parent case (d'Auria) have similar components. The first component is a semiconductor laser diode. The second component is one or more optical transport fibers with the entrance sides aligned with the emitter region of the laser diode. Light from the laser diode enters the transport fibers and is carried along the length thereof to an exit face of

the fibers. Light exiting the fibers can be advantageously used to pump a laser gain medium. Use of the fibers allows the pump source (diode) to be physically separate from the gain medium.

The third significant component of the module is a cylindrical lens, positioned between the laser diode and the array of fibers, for increasing the amount of light coupled into the entrance faces of the optical fibers. The cylindrical lens, which in the preferred embodiment is also an optical fiber, functions to capture light rapidly diverging from the array and focus it into the array of optical fibers.

In the d'Auria structure, a base or substrate is provided onto which <u>both</u> the transport fiber 2 <u>and</u> the focusing lens 3 are mounted. More particularly, d'Auria teaches that it is necessary to accurately align the transport fiber on the substrate between dowels 51, 52 and 53. The transport fiber is placed onto the substrate and secured in place with adhesive. (See column 3, line 15+). Next, the fiber lens is mounted onto the substrate. Alignment is achieved using additional dowels 54 and 55. The focusing lens 3, like the transport fiber, is attached to the substrate with an adhesive (column 3 line 47+). d'Auria teaches that an "index matching" liquid can be added between the fiber and the lens to promote coupling (column 3, line 55+). As can be seen, in d'Auria, both the transport fiber and the lens are mounted to the substrate in a fixed relationship defined by the dowels and the substrate. d'Auria also notes that separate shims 32, 32 might also be needed to control the alignment (column 3, line 55+).

The arrangement described in d'Auria is complex and time consuming to assemble. The laser diode module of the subject invention provides a far better and simpler solution to the alignment problem.

As brought out more clearly in the amended apparatus claims, in the subject invention, <u>only</u> the transport fibers are mounted to a holder. The focusing lens, on the other hand, is glued <u>directly</u> to the light entrance sides of the fibers. The glue functions to automatically self-center and align the lens with the fibers without the need for attaching the lens to the support. (See applicant's Figure 6 where lens 22 is shown attached only to the fibers and not to support 50). This difference is significant because there is no need to separately align the lens with respect to the support.

In the Office Action in the parent case, the Examiner admitted that d'Auria failed to teach gluing the lens to the fibers but argued that such gluing would be obvious since the lens is glued to the substrate. Applicant strongly disagrees.

One skilled in the art reading d'Auria understands that alignment is achieved by mounting the lens to the substrate in a manner to abut the dowels. d'Auria provides <u>no motivation whatsoever</u> to add the step of gluing the lens to the entrance ends of the fiber to provide alignment. In fact, d'Auria <u>teaches away</u> from this concept since it discloses adding an index matching fluid between lens and fiber ends.

More importantly, even if the Examiner was correct and one skilled in the art would add glue between the lens and the fibers in d'Auria, the resulting structure would still not read on the

amended apparatus claims. More particularly, even if one skilled in the art were to glue the lens to the fibers in the d'Auria structure, the resulting structure would still include the lens, glued and aligned to the substrate with the dowels. There is no suggestion in d'Auria to omit the step of attaching the lens to the substrate. In contrast, applicant's amended apparatus claims now make clear that the lens is mounted to the fibers independent of the support. This provides a clear distinction over the d'Auria structure even as modified by the Examiner.

Another significant problem with the rejection in the parent case is that it relies on the Examiner's position that "it was well known in the art to glue a lens or lenses to an entrance side of an optical fiber." The Examiner, however, fails to provide any support for this supposed knowledge. Applicant is not aware of such a teaching and it is improper for the Examiner to maintain this position without offering some evidence to support it.

In the Office Action in the parent case, the Examiner also cited the patents to Comerford and Scrifes. Comerford, like d'Auria, illustrates a device wherein both the transport fibers and the lens are mounted on a substrate. Scrifes was cited for its teaching of using a laser diode module to pump a solid state gain medium. Neither the Comerford nor Scrifes references overcome the deficiencies of d'Auria in anticipating or rendering obvious applicant's invention.

Based on the above, it is respectfully submitted that the amended claims define patentable subject matter and early allowance is respectfully requested.

Respectfully submitted,
LIMBACH & LIMBACH

Dated: April 1, 1999

By: ______________________
Michael A. Stallman
Reg. No. 29,444

Attorneys for Applicant(s)

Atty Docket No. COHD-3252

AN ASSEMBLY FOR FOCUSING AND COUPLING THE RADIATION PRODUCED BY A SEMICONDUCTOR LASER INTO OPTICAL FIBERS

CROSS REFERENCE TO PRIOR APPLICATIONS

This application is a Continuation of Application No. 08/047,421, filed April 14, 1993.

TECHNICAL FIELD OF THE INVENTION

The present invention relates to an assembly for focusing and coupling the radiation produced by a semiconductor laser diode) into an optical fiber, in particular a multimode optical fiber, with a radiation-focusing element in the form of a cylinder lens being disposed in the area between a radiating surface of the laser and a light entrance side of the optical fiber, the cylinder lens being oriented substantially parallel to the multimode direction of the radiating surface of the semiconductor laser.The invention also relates to a laser module having a plurality of assemblies of the type defined above. Finally the invention relates to an assembly for focusing and coupling the emissions produced by a semiconductor laser array (laser diode array) or a two-dimensional semiconductor laser structure (laser diode stack) into a corresponding number of individual optical fibers, in particular multimode optical fibers, with an optical system for focusing radiation being provided in the area between the radiating surface of

the laser diode array or stack and the individual light entrance sides of the optical fibers.

DESCRIPTION OF BACKGROUND ART

The source "Applied Optics", Vol. 16, no. 7, July i977, pp. 1966-1970, discloses an assembly having the features described in paragraph 1 of the "Technical field of the invention" above. This source (see in Figure 5 on p. 1968) describes a specially designed carrier element for coupling a semiconductor laser, e.g. a GaAs diode, and an optical fiber having a circular cross section, said element simultaneously carrying the cylinder lens for coupling the laser radiation produced by the GaAs diode into the subsequent optical fiber. This substantially cylindrical carrier element is provided on the top with a given number of V-groove recesses which are preshaped by mechanical, i.e. metal-removing, processing of the carrier element material, e.g. copper, in accordance with the intended coupling between laser, cylinder lens and optical fiber and in order to guarantee the necessary optical adjustment of these elements to one other. Due to this design of the carrier element the optical elements subsequent to the GaAs diode, i.e. the cylinder lens and the optical fiber, can be inserted into these above-mentioned recesses, the mutual adjustment of these elements being dependent on the precision with which the corresponding recesses have been machined in the carrier element. Very low tolerances are of course permissible here to allow for the necessary ultimate adjustment.

The mechanical requirements for the tolerances of such a carrier element, and in particular the required positioning accuracy for the GaAs diode relative to the subsequent optical elements, are thus extremely high since particularly this laser diode must be applied and fastened to the surface of the

carrier element, for example by gluing or soldering. This means that the production and processing of such a carrier element is very elaborate to permit the necessarily very low tolerances to be met.

This known assembly is intended to focus as much as possible of the radiation emitted by one semiconductor diode into the core of the optical fiber, e.g. a multimode fiber with a circular cross section. There is no intention here to provide a laser module with the greatest possible power and radiation quality.

Further, "Applied Optics", Vol. 17, No. 3, 1978, p. 479 ff., discloses an assembly wherein each individual laser of a monolithic laser diode array is coupled by means of a common cylinder lens to a great number of individual optical fibers. A carrier element in the form of a silicon substrate is likewise used here, a given number of V-shaped recesses being preshaped in this silicon substrate in accordance with the intended arrangement of cylinder lens and optical fibers for coupling between a laser diode and an optical fiber as in the known coupling assembly explained above.

Extremely low process tolerances are also permissible in this case. In addition, the direct contact between cylinder lens and laser diode array can drastically change the properties of the individual laser diodes, i.e. the laser diodes can very easily be mechanically destroyed when the cylinder lens is inserted into the V-shaped groove provided in the silicon substrate. In this latter assembly the manufacturing expenditure is therefore likewise considerable.

SUMMARY OF THE INVENTION

In view of the prior art described above the present invention is therefore based on the problem of providing an improved assembly for focusing and coupling the radiation produced by a semiconductor laser into an optical fiber, in particular a multimode optical fiber, primarily with the goal of realizing a highly efficient coupling between a multimode high-power laser diode and a multimode optical fiber. The invention is also based on the problem of providing a laser module, in particular a pumping module, with much greater power and maximum radiation quality as compared with known laser diode modules.

Finally there is also the requirement that assemblies utilizing the above-described type of coupling should be able to be produced in a much simpler and less expensive way compared with the prior art explained above, while ensuring all requirements for the precision of adjustment. The first mentioned problem is solved according to the invention by adapting a cylinder lens of the above-mentioned type to have a substantially equal to the width of a beam exit window defining the radiating surface of the semiconductor laser and whose diameter is substantially on the order of magnitude of the core diameter of the optical fiber, and preferably smaller than this core diameter, and by directly gluing the lens to, fusing the lens with or melting the lens onto the light entrance side of the optical fiber extending substantially at right angles to the orientation of the cylinder lens.

Further, the present invention makes it possible to obtain a laser module with high power and high radiation

quality while having a small numerical aperture. A given number of individual assemblies designed according to the present invention are united into a module, the corresponding individual optical fibers being bunched such that the free ends, i.e. the light exit sides, of all optical fibers are disposed in a configuration that can be selected or predetermined at will.

A laser module of the type characterized above can be used in preferred fashion as a pumping laser for systems with pumped solid state lasers, the total laser radiation obtained on the light exit sides of the bunched optical fibers serving as the pumping energy for the subsequent pumped laser.

Such optical pumping (longitudinal and transversal) can be performed for example with or without frequency multiplication, for example for pumping a neodymium-YAG laser. It is also possible to use a laser module of the type characterized above as a laser particularly for medical applications or for materials processing. In such cases, the total laser radiation obtained on the light exit sides of the bunched optical fibers is utilized as the energy for the particular medical treatment process or the particular materials processing operation.

Furthermore the light exit sides of the bunched optical fibers can preferably be combined in a matrix-shaped assembly or a linear assembly. According to yet another feature of the invention any desired symbols can be applied in matrix form to an object as "laser marking" by a preferably selective and individual drive of the individual diode lasers and imaging on the object.In a corresponding way, machining places can be preselected in

matrix form strictly by the electric drive of the individual diode lasers, which provides special advantages in particular for micromachining, e.g. when soldering, welding or drilling.

A further possibility of designing a laser module within the scope of the present invention is to couple and combine the radiating surfaces of laser diode arrays or of two-dimensional structures, so-called laser diode stacks, into corresponding optical fibers, instead of using individual assemblies of the type explained above each having individual laser diodes.

In an assembly for focusing and coupling the emissions produced by a semiconductor laser array or a two-dimensional semiconductor laser structure into a corresponding number of individual optical fibers according to the features of yet another embodiment of the invention,the optical system for focusing radiation is formed by a cylinder lens dimensioned in accordance with the number and arrangement of the individual optical fibers and oriented substantially parallel to the multimode directions of radiation of each laser diode. The length of the lens is adapted substantially to the total width of the beam exit windows defining the radiating surface of the laser diodes and its diameter is substantially on the order of magnitude of and preferably smaller than the core diameter of the particular individual optical fiber. The cylinder lens is directly glued to, fused with or melted onto all associated light entrance sides of the optical fibers extending substantially perpendicular to the orientation of the cylinder lens.

According to further advantageous embodiments of the assembly, if semiconductor laser arrays are used, the individual cylinder lens is preferably formed as a glass fiber lens. The same applies if two-dimensional semiconductor laser stacks are used. The additional advantage of such semiconductor laser arrays or stacks is their high-precision production and the related low positional tolerance of the radiating surfaces of the corresponding semiconductor lasers or laser diodes.

A relatively small air gap may preferably be provided between the laser diode array or stack and the assembly of the cylinder lens of the optical system for focusing radiation, regarded in the directions of radiation. This avoids mutual mechanical influence between the cylinder lens and the accordingly associated laser diodes, with the advantage that neither the properties of these laser diodes are changed nor is there a danger of the laser diodes being mechanically destroyed.

The invention furthermore includes the very advantageous possibility of coupling the laser diode array or stack to the associated number of individual optical fiber-cylinder lens units by providing a holding means common to all these units. Using standard techniques (etching, CNC milling and the like) one can produce structures for such holding means in a very simple and inexpensive way with a tolerance in the micrometer range sufficient for the desired coupling of the laser diode arrays or stacks to the corresponding number of optical fibers.

If the cylinder lens is glued on for example with the aid of an epoxy adhesive, one additionally obtains the

special advantage that this adhesive centers the cylinder lens or fiber lens itself on the light entrance sides of the individual optical fibers. A further advantage of the direct gluing method is obtained by using an epoxy adhesive that is very thin and has very low absorption at the laser wavelength of approximately 810 nm emitted by the laser diodes for example. Excess adhesive tends to increase the coupling efficiency even further.

On the basis of first experiences it can be said that a coupling efficiency of about 70% is typically obtainable, but a coupling efficiency up to almost 100% is also theoretically possible.

If a semiconductor laser array (laser diode array) or a two-dimensional semiconductor laser structure (laser diode stack) is provided in an assembly according to the present invention this assembly can also be used as a pumping laser for systems with pumped solid state lasers, the total laser radiation available on the light exit sides of the preferably bunched optical fibers serving as the pumping energy for a subsequent pumped laser.

It is especially advantageous to bunch all individual optical fibers of the corresponding semiconductor laser array or the corresponding two-dimensional semiconductor laser stack in such a way that the free ends, i.e. the light exit sides, of these optical fibers are disposed in configurations that can be selected or predetermined at will.

For example, a configuration can be provided such that the free ends (light exit sides) of the optical fibers are combined in a geometrically closest packing.

Furthermore, a configuration can be selected such that

the free ends (light exit sides) of all optical fibers form a substantially rectangular matrix. On the other hand, a configuration is also possible such that the free ends (light exit sides) of all optical fibers form a line.

Finally, it is also possible to drive the individual laser diodes selectively and individually so that the radiation emerges from a corresponding selection of light exit sides of the optical fibers, allowing the production of beam exit patterns that can be selected or predetermined at will.Using such an assembly one can for example mark an object with a pattern representing whole letters, numbers or other symbols in matrix form or representing parts of letters, numbers or other symbols so that several matching parts result side by side in whole letters, numbers or other symbols in matrix form.

The ends of the combined fibers can be imaged on a given place on an object (the image plane) either directly, if the distance to the image plane is small relative to the total diameter of the fiber bundle, or with the aid of an optical system, so that the laser light of the luminous fiber ends produces on the surface of this object a change which causes the desired marking of the object.

There are a number of preferred possibilities of application for the inventively designed assembly. For example, one such application is to use the assembly as a pumping laser for systems with pumped solid state lasers, the laser radiation obtained on a light exit side of the optical fiber serving as the pumping energy for the subsequent pumped laser.

The possibility of use described above also exists, for example, when, a given number of assemblies according to any of the embodiments are united into a module, the corresponding optical fibers of these individual assemblies being combined such that the free ends (light exit sides) of all optical fibers are disposed in a configuration that can be selected or predetermined at will. Furthermore, an inventively designed assembly or a corresponding laser module can be preferably used for tissue removal, coagulation, heat treatment, stimulation or other optical treatments in the medical field, or for materials processing, the laser radiation obtained on the light exit side of the assembly or the laser module serving to produce the above-mentioned effects.

If an inventive assembly or an inventive laser module is used for flexible materials processing or for tissue treatment it is also possible for the ends of the combined fibers to be imaged on a given place on a workpiece or tissue (i.e. the image plane) either directly, if the distance to the image plane is small relative to the total diameter of the fiber bundle, or with the aid of an optical system, the desired materials processing or tissue treatment then occurring at this place.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention shall be explained in more detail in the following with reference to embodiment examples and to the enclosed drawings, in which:

Figure 1 shows schematically a top view of a preferred assembly for focusing and coupling the radiation produced

by a laser diode into a multimode optical fiber with a circular cross section;

Figure 2 is a schematic side view of the assembly according to Figure 1;

Figure 3 is a schematic side view of a second preferred embodiment of an assembly for focusing and coupling the radiation produced by a laser diode into a multimode optical fiber which in this case has a rectangular cross section;

Figure 4 shows schematically a sectional view through a preferred assembly for focusing and coupling the emissions produced by a number of laser diodes disposed in a group, i.e. a so-called laser diode array, into a corresponding number of individual optical fibers with a circular cross section;

Figure 5 shows a another preferred embodiment of an assembly for focusing and coupling the emissions produced by a laser diode array into a corresponding number of individual optical fibers which in this case have a rectangular cross section (showing a schematic top view of this assembly); and

Figure 6 shows a schematic side view of the assembly according to Figure 5.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 shows a schematic top view of an assembly provided with a multimode optical fiber 4 having a

circular cross section for focusing and coupling the radiation produced by a laser diode 1 in the form of a chip.The diameter of the fiber core of optical fiber 4 is for example 200 micrometers. The dimensions of the chip forming laser diode 1 are for example 800 micrometers in length and 500 micrometers in width. This is preferably a so-called high-power laser diode with a beam exit window 11 whose area is for example 200 micrometers by 0.5 micrometers. The width of beam exit window 11 can also vary within a range between 50 and 500 micrometers, and the radiating surface can also consist of many small, closely packed individual emitters. Beam exit window 11 of laser diode 1 emits a multimode laser beam with a typical aperture angle of 10 to 12°. This corresponds to a numerical aperture of about 0.1. The direction of a multimode laser beam extends in the wide direction of laser diode 1, this multimode direction of laser diode 1 being indicated in Figure 1 by arrow Pf_1.

However, in the very small height of beam exit window 11 (0.5 micrometers) laser diode 1 radiates in the basic mode (TEM_{00}) at an angle of 400 to 600 corresponding to the height of the luminous area, corresponding to a numerical aperture of about 0.4. Figure 1 also denotes the electric leads to laser diode 1 by reference numbers 7, 8, 9 and 10.

Multimode optical fiber 4 which is circular in the preferred embodiment is disposed so that its light entrance side 5 is spaced opposite beam exit window 11 of laser diode 1, light entrance side 5 being oriented substantially parallel to the multimode direction according to arrow Pf_1 of the radiating surface of laser

diode 1.

Light entrance side 5 of multimode optical fiber 4 is also provided with a radiation-focusing element in the form of a cylinder lens 3 which is glued directly to light entrance side 5 by means of an epoxy adhesive 13 (cf. Fig. 2).

Cylinder lens 3 is thus likewise oriented substantially parallel to the multimode direction according to arrow Pf_1 of the radiating surface of light exit window 11 of laser diode 1. Length L_z of cylinder lens 3 is adapted substantially to the width of beam exit window 11 defining the radiating surface of laser diode 1. In any case, length L_z of cylinder lens 3 should not be smaller than the width of beam exit window 11, and L_z will generally be somewhat greater than the width of beam exit window 11 in the multimode direction.

Fig. 2 shows a schematic side view of the assembly according to Figure 1. The TEM_{00} direction of laser diode 1 is indicated here by arrow Pf_2. The angle of radiation of the TEM_{00} direction of laser diode 1 is denoted as 12, the numerical aperture being e.g.

0.4 as already mentioned. Diameter D_z of cylinder lens 3 is generally selected so as to be in the order of magnitude of core diameter D_x of optical fiber 4.

In the preferred embodiment explained here, however, diameter D_z of cylinder lens 3 is selected in a range between 80 and 100 micrometers and is thus below core diameter D_x = 200 micrometers of optical fiber 4. If optical fibers with a circular cross section are used, diameter D_z of cylinder lens 3 will preferably be smaller than core diameter D_x of optical fiber 4.

Cylinder lens 3 glued directly to light entrance side 5 of optical fiber 4 makes it possible for virtually the total light of laser diode 1 to be focused into the core of optical fiber 4. This is virtually an imaging of the TEM_{00} direction of laser diode 1 onto light entrance side 5 of multimode optical fiber 4 with the aid of the optical properties of cylinder lens 3.

The size and numerical aperture of optical fiber 4 are preferably selected so as to correspond to the width and the angle of radiation or the numerical aperture in the multimode direction of laser diode 1. The epoxy adhesive used by way of example for gluing cylinder lens 3 to light entrance side 5 of optical fiber 4, is very thin and has a comparatively low absorption at the laser wavelength of e.g. 810 nm produced here.

As has been shown in practice, excess adhesive tends to increase the coupling efficiency between laser diode 1 and optical fiber 4 even further. The obtained coupling efficiency is for example 70%.

For cylinder lens 3 one can preferably use a fiber lens which in the simplest case consists of a piece of customary glass fiber. However there are also fiber lenses on the market which are especially intended for imaging laser diodes and are likewise well suited as cylinder lenses in the case of the present invention. Instead of gluing cylinder lens 3, for example a fiber lens, directly onto light entrance side 5 of optical fiber 4 one can also melt cylinder lens 3 directly onto optical fiber 4, this being done for example with the aid of a CO_2 laser or an arc or the like.

Such melting is useful in particular when the multimode

optical fiber is a fiber with a substantially rectangular cross section, as is explained in more detail with reference to Figure 3. Figure 3 is a side view corresponding to Figure 2 of an assembly for focusing and coupling the radiation produced by a laser diode 1 into a multimode optical fiber 4' which has a rectangular cross section and the dimensions of for example 200 micrometers in width and 20 micrometers in height. A cylinder lens or fiber lens 3 is again glued directly to light entrance side 5 of multimode optical fiber 4, cylinder lens 3 in this case having a diameter of for example 20 micrometers, corresponding to the height of rectangular optical fiber 4'. However diameters of cylinder lens 3 in the order of magnitude of 5 to 10 micrometers are also conceivable, i.e. in the order of magnitude of the diameter of a single mode optical fiber.

As is also apparent from Figures 2 and 3, laser diode 1, e.g. a GaAs diode, is disposed on a carrier element 6, e.g. a silicon substrate.

As already explained in detail with reference to Figures 1 to 3, the principle of coupling involves the inventive assembly in direct gluing or fusion of a cylinder lens with the beam entrance side of an optical fiber which extends substantially at right angles to the orientation of this cylinder lens. This results in a virtually firm compound between the cylinder lens or fiber lens and the optical fiber, at the same time achieving a preadjustment since the cylinder or fiber lenses are centered quasi automatically on the optical fibers.

Consequently, prefabricated units including cylinder lenses and optical fibers, for example, can be kept in

stock, while for practical application in connection with a laser diode the unit need only be centered with respect to the diode but otherwise no further adjustment measures performed with respect to the coupling unit itself.

As noted above, Figure 1 denotes such an optical coupling unit including an optical fiber 4 with a circular cross section and a cylinder lens 3 glued on its face by adhesive 13, while Figure 3 depicts another such optical coupling unit including an optical fiber 4′ with a rectangular cross section and a cylinder lens 3 glued to its face.

Furthermore Figures 1 to 3 also indicate that a comparatively small air gap is provided in each case between beam exit window 11 of laser diode 1 and cylinder lens 3, regarded in the particular directions of radiation, so that an impairment of the properties of the laser diode or mechanical damage to it or even destruction of it can be avoided from the beginning. In the embodiment according to Figure 3 one can use a substantially flat, round optical fiber instead of an optical fiber with a rectangular cross section.

Figures 5 and 6 show an embodiment example of a laser module provided with a group of several multimode high-power laser diodes 23 disposed side by side, i.e. virtually a laser diode array 30, the emissions produced by individual laser diodes 23 being coupled into a corresponding number of individual multimode optical fibers with a rectangular cross section.

As in the assemblies according to Figures 1, 2 and 3 an

optical system for focusing radiation is disposed here in the area between the radiating surface of laser diode array 30 and individual light entrance sides 24 of the particular associated optical fiber 21 with a rectangular cross section. In the present embodiment example this optical system is formed by a number of assemblies of individual cylinder lenses 22 corresponding to the number and arrangement of individual optical fibers 21'.

All cylinder lenses 22 are oriented substantially parallel to the multimode direction of radiation of each laser diode 23 of laser diode array 30; also, length Lz of each cylinder lens 22 is adapted substantially to the width of a beam exit window 23' defining the radiating surface of particular laser diode 23, while diameter D_z of cylinder lenses 22 is substantially equal to the height of each individual optical fiber 21' having a rectangular cross section.

Each individual cylinder lens 22 is glued directly onto the associated light entrance side 24 of optical fibers 21' in the same way as already explained above with reference to Figures 1 to 3. One thus again obtains optical coupling units each comprising cylinder lens 22 and optical fiber 21', which are denoted in Figure 5 by reference number 40.

Furthermore, Figures 5 and 6 show that a holding means 50 is provided for coupling laser diode array 30 to the associated number of individual optical coupling units 40 including cylinder lenses and optical fibers, the holding means holding each of individual optical fibers 21' in an initially parallel side-by-side configuration. When such an assembly is mounted, laser diode array 30 and holding

means 50 are adjusted relative to each other and then fastened to a common carrier 70 shown in Figure 6, for example by screwing or gluing.

This carrier 70 is finally disposed on a Peltier element 80. To adjust the desired laser wavelength the common carrier is tempered, the tempering additionally contributing to stabilizing the coupling. In the embodiment of Figures 5 and 6 relatively small air gaps are also provided in each case between laser diode array 30 and the assembly of individual cylinder lenses 22, regarded in the directions of radiation.

It is of special importance for the assembly illustrated in Figures 5 and 6 that all optical fibers 21′ can be bunched so that their free ends, i.e. their light exit sides, are disposed in a configuration that can be selected or predetermined at will, and in particular, combined in a geometrically close packing. In practice this means that individual laser diodes 23 in laser diode array 30 can be coupled into a very high-power laser module by first coupling laser diode array 30 to optical fibers 21′ having a rectangular cross section and then stacking the fibers on the light exit side into a preferably square bundle 90, for example a bundle with edge lengths of 220 micrometers by 220 micrometers and a numerical aperture of 0.11.

Finally, Figure 4 shows an example of the preferred embodiment of an assembly for focusing and coupling the emissions produced by a semiconductor laser array into a corresponding number of individual multimode optical fibers 21, in which one uninterrupted cylinder lens 60 is provided in the area between the radiating surface of the

laser diode array (located behind the paper plane in Figure 4) and the individual light entrance sides of optical fibers 21.

Cylinder lens 60 is formed for example by an appropriately long piece of a fiber lens which is dimensioned such that its length is adapted substantially to the sum of the widths of the particular beam exit windows defining the radiating surfaces of all laser diodes of the array, the diameter of cylinder lens 60 preferably being smaller than the particular core diameter of each optical fiber 21, as in the embodiment of Figure 1. Common cylinder lens 60 is again glued onto, fused with or melted onto all light entrance sides of optical fibers 21 extending substantially perpendicular to the orientation of cylinder lens 60.

Optical fibers 21 located side by side in parallel are again held by a holding means 50 which has corresponding V-shaped grooves 51 on the top for insertion of optical fibers 21. This holding means 50 is then adjusted to the associated laser diode array, in the way already explained with reference to Figure 6, 50 that this adjusted assembly can in turn be fastened to a common carrier as shown in Figure 6.

In the embodiment shown in Figure 4 the light exit sides of optical fibers 21 with a round cross section can then be combined into a bundle. For example, twelve free optical fiber ends are combined into a bundle with a diameter of about 900 micrometers, a numerical aperture of 0.11 and an output power of about 7 W.

On the basis of the assemblies shown for example in Figures 4, 5 and 6 one can produce high-power laser

modules (up to 50 W) which are very suitable as pumping lasers for end-pumped solid state lasers, to be applied for example in medicine or for soldering or the like.

WHAT IS CLAIMED IS:

1. A method of coupling laser radiation from a linear laser diode array into a plurality of optical fibers corresponding in number to the number of laser diodes in the laser diode array, each of the optical fibers having a light entrance side, the method comprising the steps of:
(a) providing a cylinder lens having at least the length of the linear laser diode array;
(b) arranging the light entrance sides of the optical fibers parallel to each other in a linear array;
(c) gluing the cylindrical lens onto said linear array of light entrance sides of the optical fibers; and
(d) positioning said linear array of light entrance sides of the optical fibers and said cylindrical lens glued thereon, such that said cylindrical lens is aligned with the linear array of laser diodes for receiving radiation emitted therefrom and focussing said received radiation into said plurality of optical fibers.

2. The method of claim 1, wherein in step (c) said gluing causes said cylindrical lens to be centered on said linear array of entrance ends of the optical fibers.

3. The method of claim 1 wherein said cylindrical lens is a length of optical fiber.

4. The method of claim 3, wherein in step (c) said gluing causes said cylindrical lens to be centered on said linear array of entrance ends of the optical fibers.

5. The method of claim 4, wherein in step (c) said gluing is by means of an epoxy adhesive.

6. A method of coupling laser radiation from a linear laser diode array into a plurality of first optical fibers corresponding in number to the number of laser diodes in the laser diode array, each of the first optical fibers having a core diameter and a light entrance side, the method comprising the steps of:
(a) providing a second optical fiber having at least the length of the linear laser diode array;
(b) arranging the entrance sides of the first optical fibers parallel to each other in a linear array;
(c) gluing the second optical fiber onto said linear array of entrance sides of the first optical fibers, said gluing step centering said second optical fiber on said linear array of entrance ends of the first optical fibers; and
(d) positioning said linear array of entrance sides of the first optical fibers and said second optical fiber glued and centered thereon, such that said second optical fiber is aligned with the linear array of laser diodes for receiving radiation emitted therefrom and focussing said received radiation into the plurality of first optical fibers.

7. The method of claim 6 wherein said first optical fibers are multimode optical fibers.

8. The method of claim 7 wherein said second optical fiber has a diameter less than the core diameter of the first optical fibers.

9. The method of claim 8 wherein said gluing is by means of an epoxy adhesive.

10. In a laser diode module wherein laser radiation from a linear laser diode array is coupled into a plurality of optical fibers corresponding in number to the number of laser diodes in the laser diode array, each of the optical fibers having a light entrance side, the invention characterized in that:

the light entrance sides of the optical fibers are arranged parallel to each other in a linear array;

a cylindrical lens having at least the length of the linear laser diode array is glued onto said linear array of light entrance sides of the optical fibers; and

said linear array of light entrance sides of the optical fibers and said cylindrical lens glued thereon is aligned with the linear array of laser diodes for receiving radiation emitted therefrom and focussing said received radiation into said plurality of optical fibers.

11. The laser diode module claim 10, the invention further characterized in that said cylindrical lens is centered on said linear array of light entrance sides of the optical fibers.

12. The laser diode module claim 11, the invention further characterized in that said cylindrical lens is a length of optical fiber.

13. The laser diode module claim 12, the invention further characterized in that, in step (c) said gluing causes said

cylindrical lens to be centered on said linear array of entrance ends of the optical fibers.

14. The laser diode module claim 13, the invention further characterized in that, in step (c) said gluing is by means of an epoxy adhesive.

15. In a laser diode module wherein laser radiation from a linear laser diode array is coupled into a plurality of first optical fibers corresponding in number to the number of laser diodes in the laser diode array, each of the first optical fibers having a core diameter and a light entrance side, the invention characterized in that:

the light entrance sides of the first optical fibers are arranged parallel to each other in a linear array;

a second optical fiber having at least the length of the linear laser diode array is glued onto said linear array of entrance sides of the first optical fibers and centered thereon; and

said linear array of light entrance sides of the first optical fibers and said second optical fiber glued and centered thereon is aligned with the linear array of laser diodes for receiving radiation emitted therefrom and focussing said received radiation into said plurality of first optical fibers.

16. The laser diode module claim 15, the invention further characterized in that said first optical fibers are multimode optical fibers.

17. The laser diode module claim 16, the invention further characterized in that said second optical fiber has a diameter less than the core diameter of the first optical fibers.

18. The laser diode module claim 17, the invention further characterized in that said gluing is by means of an epoxy adhesive.

ABSTRACT OF THE DISCLOSURE

An assembly for focusing and coupling radiation produced by a semiconductor laser into an optical fiber, in particular a multimode optical fiber, including a radiation-focusing element in the form of cylinder lens disposed in the area between the radiating surface of the semiconductor laser and light entrance side of the optical fiber, the length of the cylinder lens being at least equal to a width of a beam exit window defining the radiation surface of the semiconductor laser, and the diameter of the cylinder lens being substantially on the order of magnitude of the core diameter of the optical fiber. The cylinder lens is in the form of glass fiber lens directly glued onto, fused with, or melted onto the light entrance side of the optical fiber which extends substantially at right angles to the orientation of the cylinder lens. The assembly can be used in particular to produce high-powered laser modules up to 50 watts and are very suitable as pumping laser for an end-pumped solid state laser, for example for medical applications or for materials processing.

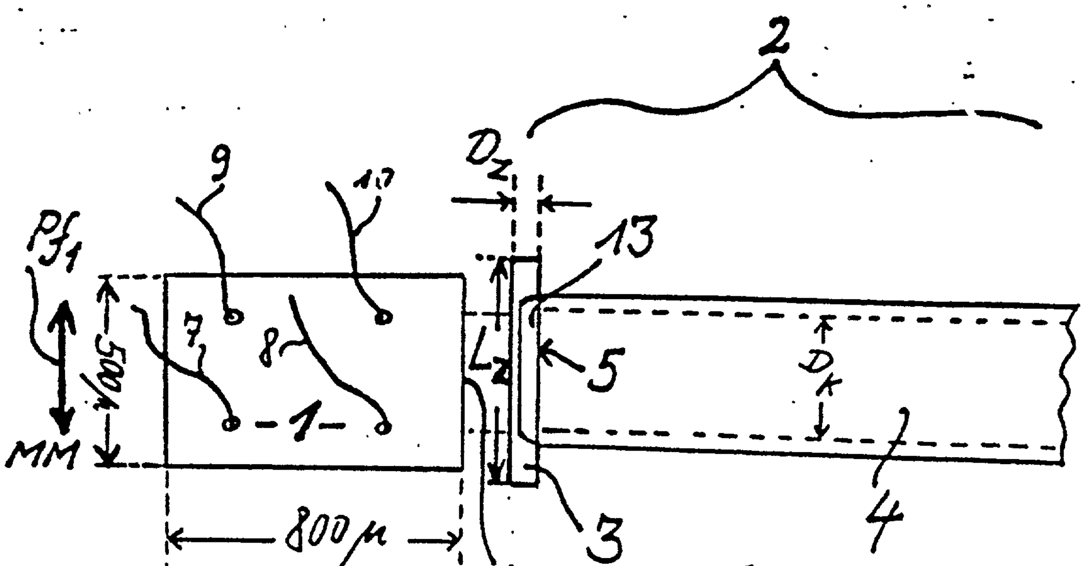

Fig. 1

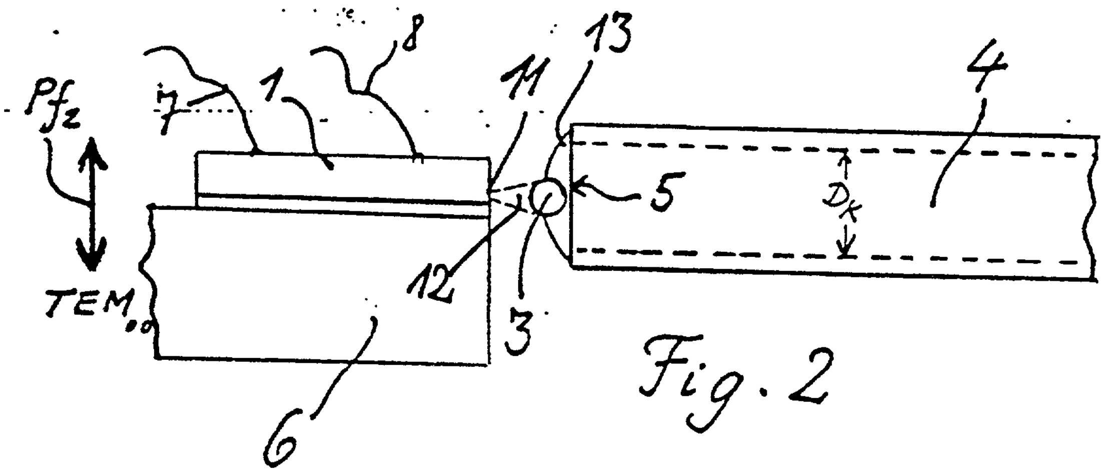

Fig. 2

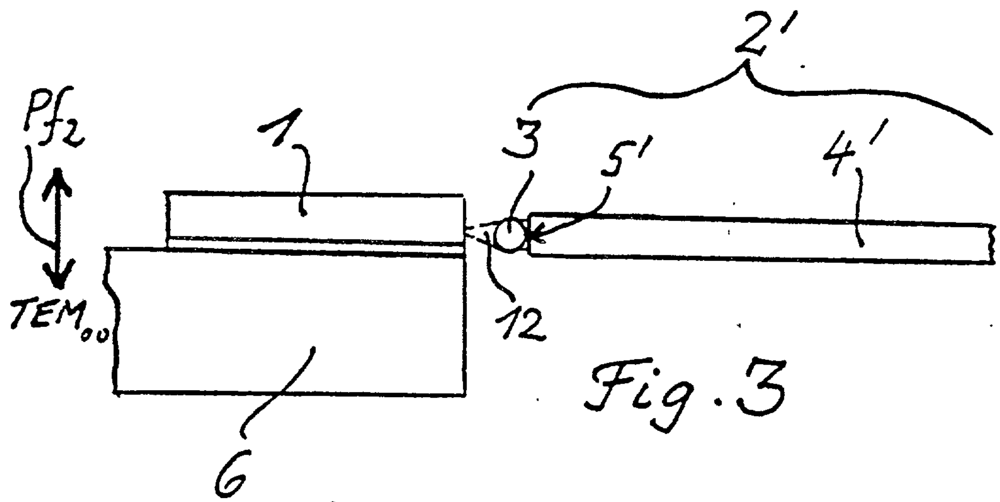

Fig. 3

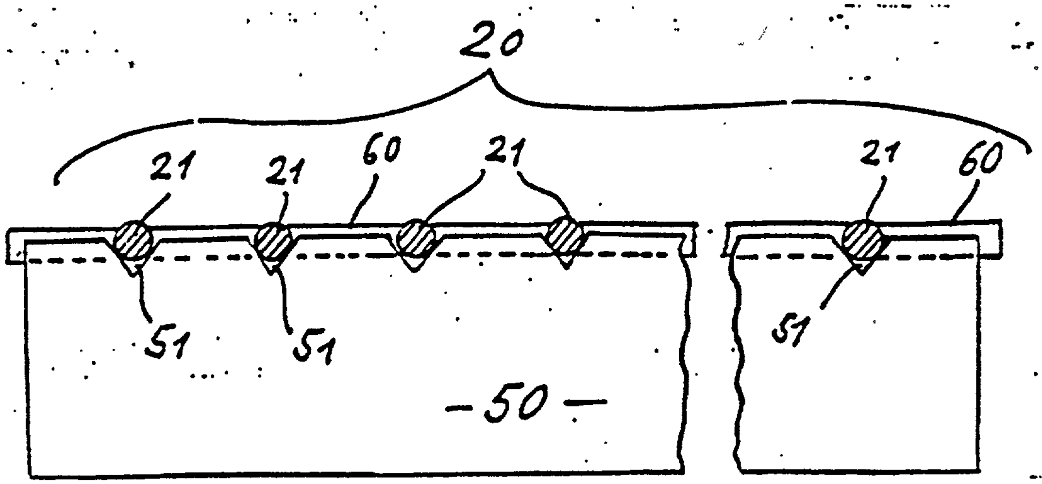

Fig. 4

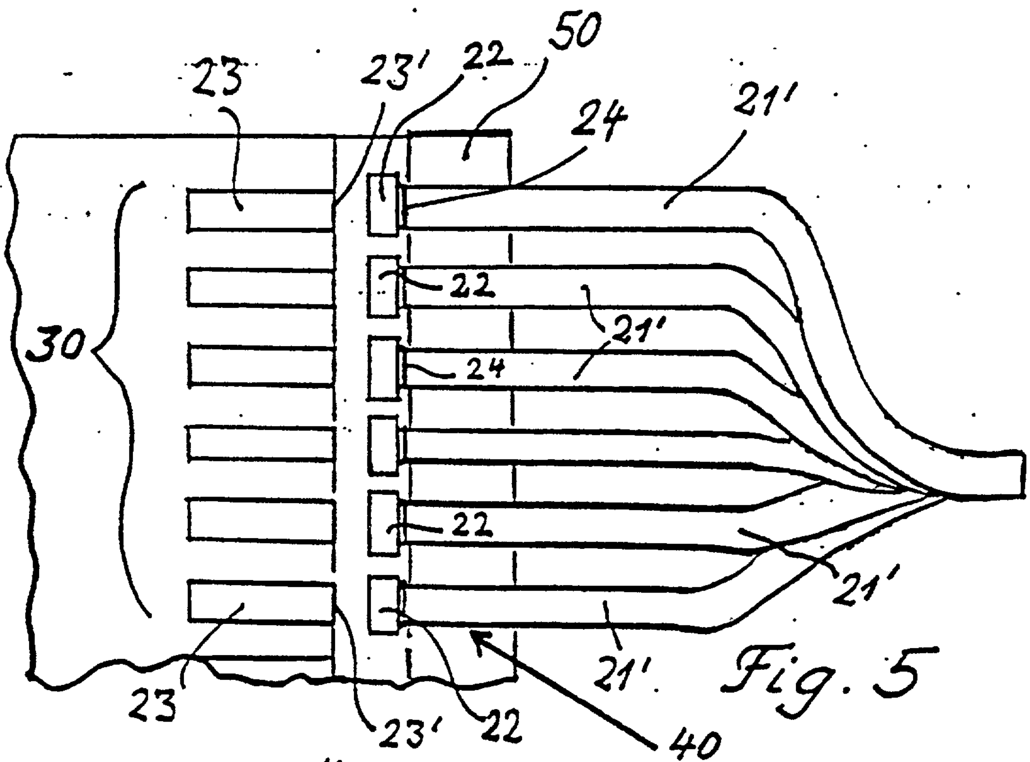

Fig. 5

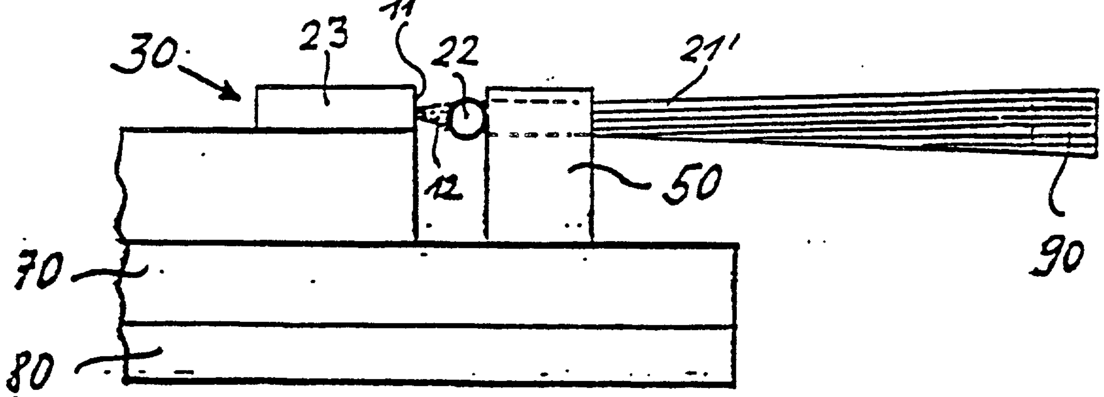

Fig. 6

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Atty Docket No. COHD-3251

DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

AN ASSEMBLY FOR FOCUSING AND COUPLING THE RADIATION PRODUCED BY A SEMICONDUCTOR LASER INTO OPTICAL FIBERS

the specification of which (check one) _X_ is attached hereto or ___ was filed on ________________ as Application No. ____________________________ and was amended on __________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information which is material to patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

			Priority Claimed Yes	Priority Claimed No
Number	Country	Day/Month/Year Filed	___	___
Number	Country	Day/Month/Year Filed	___	___

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) below.

Application Number	Filing Date
Application Number	Filing Date

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Application Number	Filing Date	Status: Patented, Pending, Abandoned
08/047,421	April 14, 1997	Pending

Application Number	Filing Date	Status: Patented, Pending, Abandoned

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under 18 U.S.C. § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Attorney Docket No. COHD-3251

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR UNITED STATES PATENT

In re Patent Application of Jörg Lawrenz-Stolz Appln. No. 08/982,018 Filed: December 1, 1997 For: AN ASSEMBLY FOR FOCUSING AND COUPLING THE RADIATION PRODUCED BY A SEMICONDUCTOR LASER INTO OPTICAL FIBERS	Group Art Unit: 2874 **POWER OF ATTORNEY BY ASSIGNEE**

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

COHERENT, INC., assignee of the entire right title and interest in the above-identified application by assignment dated March 16, 1998, which assignment was recorded in the Patent and Trademark Office on March 30, 1998, at Reel 9093, frame 152, hereby appoints the members of the firm of LIMBACH & LIMBACH L.L.P., a firm composed of:

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Stephen M. Everett	30,050	Seong-Kun Oh*			
Alfred A. Equitz	30,922	Cameron A. King	P-41,897		

* Recognition under 37 CFR 10.9(b)

as its attorneys with full power of substitution to prosecute this application and to transact all business in the Patent and Trademark Office in connection therewith.

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Dated: 7-20-98

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Rev. 03/25/98